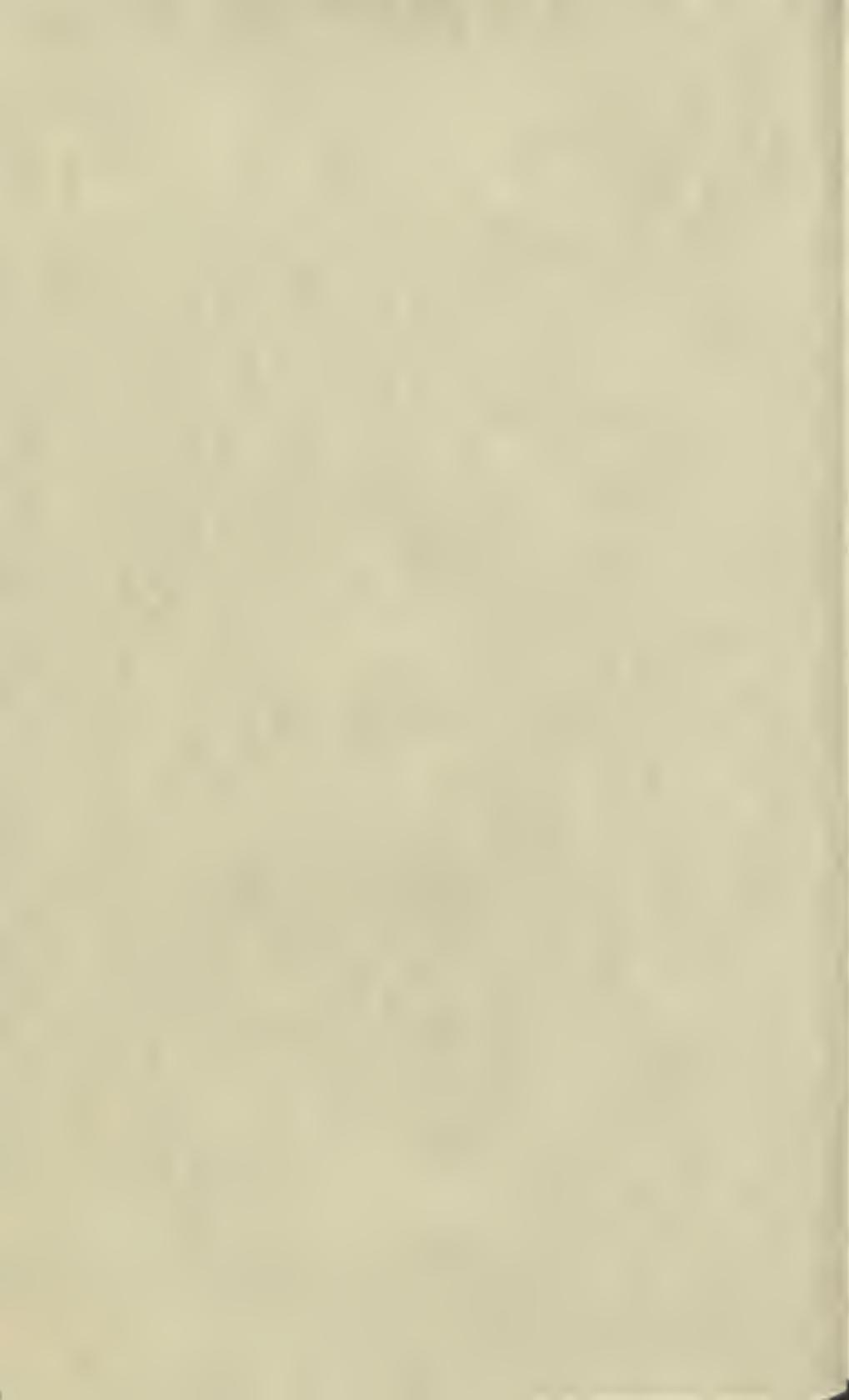






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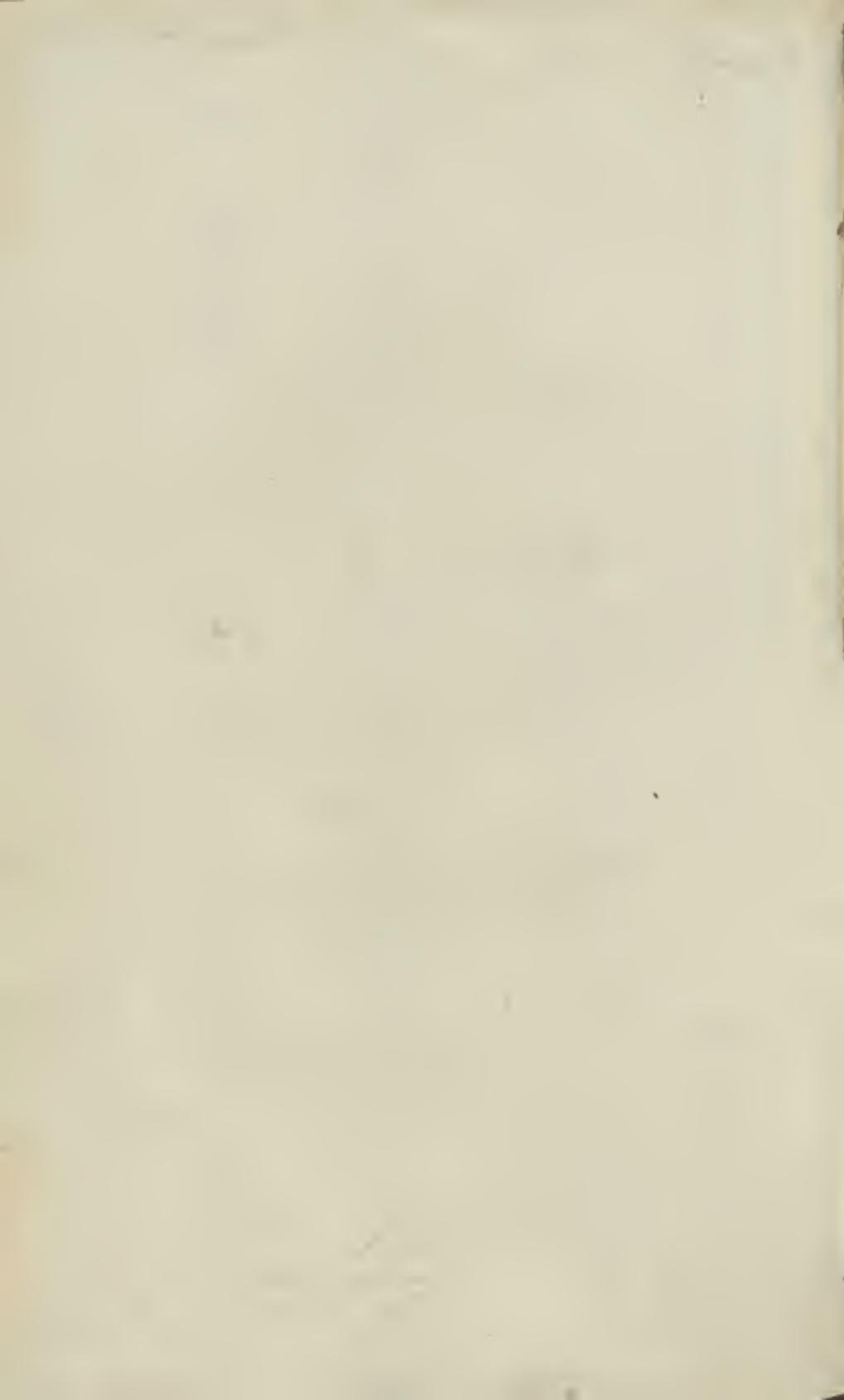




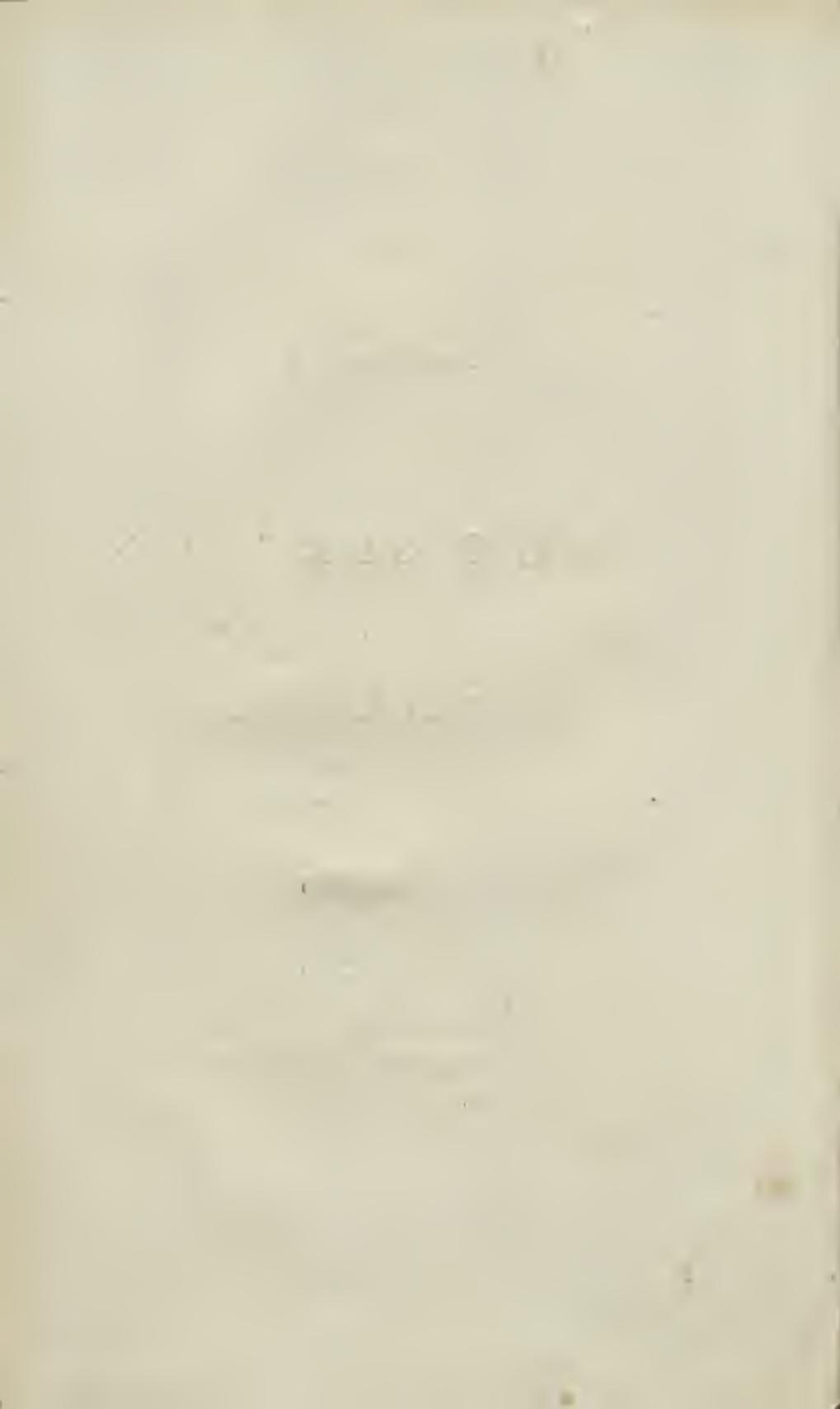


From the Author

J Holmyd



AN
ACCOUNT
OF THE
HOT SPRINGS
IN
ICELAND;
WITH AN
Analysis
OF
THEIR WATERS.



A N
A C C O U N T,
Esq.

An ACCOUNT of the HOT SPRINGS, near Rykum, in Iceland: In a Letter to Dr. BLACK, from JOHN THOMAS STANLEY, Esq. F. R. S. F. S. A. A. LOND. and F. R. S. EDIN.

[*Read, Nov. 7. 1791.*]

DEAR SIR,
Alderley, August 15, 1791.
I HAVE been prevented hitherto, by various occupations, from acquitting myself of a promise you received from me, (I am ashamed to think how long a time since), that I would send you an account

of the Hot Springs in Iceland, from whence the water was brought which you have lately analysed. I have trusted you would excuse a delay not altogether voluntary. It will be now my endeavour to gratify your curiosity as far as I am able; and to acquaint you with every particular, as well concerning the springs, as the country near them, which I think you may find in the least interesting.

We saw many springs in the course of our journey besides those I am going to describe; nor indeed are they confined to the part of the island we visited, but break out in every division of it. For a general account of the most remarkable, I refer you to a letter, written by Dr. VAN TROIL, (the present Archbishop of Upsal), to Professor BERGMAN, published with some others concerning Iceland, in the year 1777.

The descriptions given by this author are so accurate, that it will not be in my power to give you much new information. I must, in a great measure, repeat what he has said. It may be satisfactory, however, to you to have his relations corroborated; and some further details, with an account of the changes

which, in a few instances, have taken place since he visited these particular springs in 1772, may contribute to explain their history, and the cause of their very singular appearances.

You received two kinds of water, one from a spring near a farm called Rykum, and the other from the fountain known by the name of the Geyzer, the most remarkable in the island. It rises near the farm of Haukadal, about forty miles from Rykum. They are both situated in the S. W. division of the island.

I shall begin with a description of the country, and the springs near Rykum, and of the first view we had of them in our way from Rykavick to Mount Hecla. Rykum is situated in a valley, which, on account of its fertility, and the strong contrast it made with the dreary scenes we had passed since our last station, appeared to us with great advantage while we approached it. We had traversed a country, seven or eight miles in breadth, entirely overspread with lava, and other volcanic matter. It was surrounded with hills, not sufficiently high to be majestic, and too rugged and too barren to be pleasing. We were told by our guides, that on a clear day, the summits of Hecla might be

seen above those which were immediately before us; but heavy and lowering clouds, which threatened us incessantly with a storm, concealed every distant object from our sight.

We saw many districts in Iceland covered with lava; but I do not recollect one so uncouth and desolate as this. No vegetation was to be seen, but that of a few stunted bushes of willow and birch, growing between the crevices and hollows of the lava, into which the wind had drifted sufficient soil for them to take root. We could discover no mouth or crater from whence we could conjecture, with any degree of probability, the lava to have issued. It extended round us like a sea; and it had burst perhaps from some part of the country it now covered, while the fire to which it owed its origin, had escaped with its showers of cinders and ashes, from some other orifice, and had formed one of the numberless cones we could discover amidst the neighbouring hills.

The unpleasantness of our ride over this country was increased by the continual danger to which we were exposed of our horses falling. The road was no other than what the few travellers of the coun-

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try, as they passed from their farms to Rykavick, had tracked over the lava, where it was least rough; but even this was interrupted by many breaks and crevices, formed by the cooling of the matter, and the contraction of its parts.

To this uncomfortable scene succeeded the view of a rich valley, opening into an extensive green plain, bounded by the sea. A river was seen winding between several fertile meadows; and beyond these, the valley was terminated by a range of high and bold rocks. But our attention was chiefly attracted by the clouds of steam, which ascended in various parts of the valley from the hot springs, and by jets of water which, from some of them, were incessantly darted into the air.

We descended into the valley by a road winding over the lava, which in one place had flowed from the upper plain into the country below. On each side it had stopped abruptly, and had thus formed a perpendicular wall, at least sixty feet high.

We pitched our tents in a pleasant field, on the side of the river, opposite to the farm, and not far

from it; and at the foot of the hills which bounded the valley. Several fragments of rocks, which had fallen from these, lay scattered round our station. These were entirely volcanic; some of dark blue lava, not unlike basalt; others of a yellow substance; and again others of a grey lava, mixed with a great quantity of white glass: but the most curious consisted of an heterogeneous mixture of various substances, cemented indiscriminately together by some operation, subsequent to their original formation, and so strongly, that the rock was broken with difficulty by our hammers. It consisted of pieces of black glass, (a lava in all probability much vitrified), and large pieces of a close, grey lava, the cavities and pores of which were filled with zeolites finely radiated. Some pieces of black lava, in parts compact, and in other parts so porous as to approach nearly to a pumice stone, were mixed with the rest of the mass. A mixture of these same substances, (the lavas, the glass, and the zeolites), pounded in small grains, filled the spaces between the larger pieces, and connected the whole into a solid rock. The heat (if heat it was) which had cemented these materials, had not been strong enough to reduce any one to a state of fusion; for the angles of the frag-

ments were as sharply defined as if newly separated from their respective original beds.

The rocks from whence these different masses have been detached, lay heaped together in so disjointed and irregular a manner, that some violent convulsion has evidently taken place among them since their first formation; but similar appearances of disorder are to be seen in every range of hills in the country. Regular strata are no where to be met with. It appears as if all this part of the island, at different periods, had been thrown up from its foundations.

The valley is, in this place, fertile; and nearly half a mile in breadth. It becomes more narrow towards the north; and it is there rendered barren by heaps of crumbled lava, or other rubbish, brought down from the hills by the waters. These have the appearance of artificial mounds, and a great number of springs are continually boiling through them. Below the surface, a general decomposition seems taking place: for almost wherever the ground is turned up, a strong heat is felt, and the loose earth and stones are changing gradually into a clay, or bole of various colours, and beautifully veined, resembling a variegated jasper. The

heat may possibly proceed from a fermentation of the materials composing these mounds; but more probably (I should conjecture) from the springs and steam forced up through them. The springs must have acquired their heat at some greater depth, from some constant, steady cause, (however difficult to explain), adequate to the length of time they have been known to exist, with the same unvaried force and temperature.

Springs do not boil on or near these banks only. They rise in every part of the valley, and within the circumference of a mile and an half, more than an hundred might easily be counted. Most of them are very small, and may be just perceived simmering in the hole from whence the steam is issuing. This, trailing on the ground, deposits, in some places, a thin coat of sulphur. The proportion varies; for near some of these small springs, scarce any is perceptible, whilst the channels by which the water escapes from others, are entirely lined with it for several yards. Neither the water, nor the steam from the larger springs, ever appear to deposit the smallest proportion of sulphur; nor can the sulphureous vapour they contain be discovered, otherwise than by the taste of what has been boiled in them for a long time.

Many springs boil in great caldrons or basons, of two, three, or four feet diameter. The water in these is agitated with a violent ebullition, and vast clouds of steam fly off from its surface. Several little streams are formed by the water which escapes from the basons; and as these retain their heat for a considerable way, no little caution is required to walk among them with safety.

The thermometer constantly rose in these springs, to the 212th degree; and in one small opening, from whence a quantity of steam issued with great impetuosity, Dr. WRIGHT observed the mercury rise, in two successive trials, to the 213th degree.

I have already said, that the ground, through which many of the springs were boiling, was reduced to a clay of various colours. In some, the water is quite turbid; and, according to the colour of the clay through which it has passed, is red, yellow, or grey.

The springs, however, from whence the water overflows in any great quantity, are, to appearance, perfectly pure. The most remarkable of these was about fifty or sixty yards from our station, and was distin-

guished by the people of the neighbourhood, by the name of the Little Geyzer. The water of it boiled with a loud and rumbling noise in a well of an irregular form, of about six feet in its greatest diameter; from thence it burst forth into the air, and subsided again nearly every minute. The jets were dashed into spray as they rose, and were from twenty to thirty feet high. Volumes of steam or vapour ascended with them, and produced a most magnificent effect, particularly if the dark hills, which almost hung over the fountain, formed a back ground to the picture. The jets are forced, in rising, to take an oblique direction, by two or three large stones, which lay on the edge of the basin. Between these and the hill, the ground (to a distance of eight or nine feet) is remarkably hot, and entirely bare of vegetation. If the earth is stirred, a steam instantly rises, and in some places it was covered with a thin coat of sulphur, or rather, I should say, some loose stones only were covered with flakes of it. In one place, there was a slight efflorescence on the surface of the soil, which, by the taste, seemed to be alum,

The spray fell towards the valley, and in that direction covered the ground with a thick incrustation

of matter which it deposited. Close to this, and in one spot, very near the well itself, the grass grows with great luxuriance.

Where the soil was heated, it was gradually (as on the mounds) changing into a clay. But it was here more beautiful than in any other place. The colours were more varied and bright, and the veins were marked with more delicacy. The transition likewise from one substance into the other was more evident and satisfactory.

To the depth of a few inches, the ground consisted of loose lavas, broken and pounded together, of blue, red, and yellow colours. The blue lava was hardest; and several pieces of it remained firm and unaltered, while the rest were reduced to a dust. The colours became brighter, as the decomposition of the substances advanced, and they were changed at the depth of nine or ten inches into a clay; excepting, however, the pieces of dark blue lava, which still retained sufficient hardness to resist the pressure of the finger. Round these, (which appeared insulated in the midst of the red and yellow clay), several veins or circles were formed of various shades and colours. A few

inches deeper, these also became part of the clay, but still appearing distinct, by their circles, from the surrounding mass. The whole of this variegated substance rested on a thick bed of dark blue clay, which had evidently been formed in the same manner from some large fragment of blue lava, or stratum of it, broken into pieces.

The resemblance of these clays to jasper is so striking to the eye, that I cannot forbear believing their origin to be similar, at least, that some circumstances in the formation of each are the same. You will say, with reason, that the difference, notwithstanding the apparent similitude, is in reality very wide; that these clays, before they can be converted into jaspers, require to be consolidated, and impregnated with a considerable proportion of siliceous earth. It is something, however, to have detected nature in the act of forming, in any substance, the veins and figures common to marbles and jaspers. What still remains of the process, after thus much of it has been traced, may not long continue unknown; and in Iceland, probably sooner than elsewhere, will be discovered beds of clay, like this, hardening into stone, either by the effect of subterraneous heat, or pressure promoting an adhesion of the

particles, or by some insinuation of matter (perhaps siliceous) into the pores of the mafs.

There is another fountain in the valley, not much inferior in beauty to that which I have described. It breaks out from under one of the mounds, close to the river. Its eruptions are, I think, in some respects, more beautiful than those of the former. They rise nearly to the same height, and the quantity of water thrown up at one time is greater, and not so much scattered into spray. The jets continue seldom longer than a minute, and the intervals between them are from five to six minutes. They are forced to bend forwards from the well, by the shelving of the bank, or probably their height would be very considerable; for they appear to be thrown up with great force. We never dared approach near enough to look deep into the well; but we could perceive the water boiling near its surface, from time to time, with much violence. The ground in front of it, was covered with a white incrustation, of a more beautiful appearance than the deposition near any other spring in this place. By a trial of it with acids, it seemed almost entirely calcareous.

I have now described to you the two most remarkable fountains in the valley of Rykum, the only two which throw up water to a considerable height with any regularity. There are some from whence, in the course of every hour, or half hour, beautiful jets burst out unexpectedly; but their eruptions continue only a few seconds, and between them the water boils in the same manner as in the other basins.

Towards the upper end of the valley, there was a very curious hole, which attracted much of our attention. It seemed to have served at some former period as the well of a fountain. It was of an irregular form, and from four to five feet in diameter. It was divided into different hollows or cavities at the depth of a few feet, into which we could not see a great way, on account of their direction. A quantity of steam issued from these recesses, which prevented us from examining them very closely. We were stunned while standing near this cavern, and in some measure alarmed, by an amazing loud and continued noise which came from the bottom. It was as loud as the blast of air forced into the furnace from the four great cylinders at the Carron iron-works.

We could discover no water in any of the cavities; but we found near the place many beautiful petrifications of leaves and mosses. They were formed with extreme delicacy, but were brittle, and would not bear much handling; their substance seemed chiefly argillaceous.

We perceived smoke issuing from the ground in many places in the higher parts of the valley, much further than we extended our walks. I am sorry to say we left many things in this wonderful country unexamined; but we were checked in our journey by many circumstances, which allowed us neither the leisure nor the opportunity for exploring every part of it as we could have wished. The substances deposited near the different springs seemed to me, in general, a mixture of calcareous and argillaceous earths; but near one spring, not far from our tents, there seemed to be a slight deposition of siliceous matter. To the eye it resembled calcedony; but with its transparency, it had not the same hardness, and, if pressed, would break to pieces. The water you have analysed came from this spring, and we were obliged to take some care in filling the bottles; for though gradually heated, they

would break when the water was poured into them, if it had not been previously exposed to the air for some minutes in an open vessel.

The water of this spring boiled, as in most of the others, in a cauldron four or five feet broad. I do not recollect to have seen any of it ever thrown up above a foot, and some meat we dressed in it tasted very strongly of sulphur.

Mr. BAINE, by a measurement of the depth, the breadth, and the velocity of the stream flowing from the Little Geyzer, found the quantity of water thrown up every minute by it to be 59,064 wine gallons, or 78.96 cubic feet. Mr. WRIGHT and myself followed the stream, to observe how far any matter continued to be deposited by the water. We found some little still deposited where it joined the river, a quarter of a mile at least from its source. At that place, it retained the heat of 83 degrees by Fahrenheit's thermometer.

The vegetation on the banks of the stream, and in the pleasant meadows through which it flows, is ex-

ceedingly luxuriant. The farmer and his people were at this time employed in cutting the hay in them, which, though not high, was thick, and remarkably sweet. The plants which Mr. WRIGHT found in the greatest perfection, were the *sedum acre*,* the *veronica becabunga*,† the *polygonum viviparum*,‡ and the *comarum palustre*.§

A LITTLE above, where the current from the Little Geyzer falls into the river, part of the lava, which has descended from the upper into the lower plain, has assumed close to its banks, for the space of some yards, a regular columnar shape. The pillars are short, and have five or six sides. I cannot be very exact in my account of them, as they were on the opposite side of the river. I should suppose they were nearly a foot and an half in diameter. Some were horizontal, and others vertical. We observed the same appearance in many of the tracts of lava we traversed on our journey, and, in one or two instances, in those which had flowed from the sides of Mount Hecla, though the pillars there were less perfectly defined.

* Pepper stone crop.

† Snake weed.

‡ Brooklime.

§ Purple marsh ariguefoil.

So many streams of hot water fall into the river, that it receives from thence a very perceptible degree of heat. The thermometer, immersed in it above where it is joined by the waters of the Little Geyzer, rose to 67 degrees, while in the open air it stood at 60. The breadth of the river in the same place is forty feet; its mean depth two feet and an half, and its course is rather rapid. Several kinds of fish are found in it; in particular, numbers of very fine salmon.

The village of Rykum or Ryka, called either indiscriminately, from *Ryk*, an Icelandic word, signifying smoke, is situated in the middle of the valley, and, by an observation made by Mr. BAINE, is in latitude $64^{\circ} 4' 38''$ N. about twenty miles from Rykiavick, and eight or ten from Oreback, a small harbour on the southern coast of the island. The village consists of the fariner's house, and the houses of his servants or dependants, and a small church. All the adjacent lands belong to him, and he keeps a considerable number of sheep and cattle, and some few horses. These constitute his riches; and he purchases at Rykiavick, with skins, wool, and butter, whatever he requires, of which the chief article is fish, for his winter's provision.

I have now related to you every circumstance that has occurred to me worth mentioning concerning this interesting valley. I have regretted much, however, my inability to give you a more accurate account of some parts of it; in particular, of the many springs which break out near the hills to the north, and of the rocks above the field where we placed our tents, which deserved more attention than I gave to them. But we remained in this valley a short time only, and the weather, during our continuance there, was very unfavourable. I shall here close this letter, and reserve for another (which you may very soon expect) the account I have yet to send you of the Great Geyzer, and the springs near Haukadal.

I am, Dear Sir, with great esteem, your most obedient servant,

JOHN THO. STANLEY.

*An ACCOUNT of the HOT SPRINGS near Haukadal,
in Iceland: in a second Letter to Dr. BLACK, from
JOHN THOMAS STANLEY, Esq. F.R.S. F. S. A
Lond. and F. R. S. Edin.*

[*Read April 30, 1792.*]



Grosvenor Place, March 30, 1792.

DEAR SIR,

PART of my promise has been accomplished in a former letter, in which I gave you the fullest account I could of the springs of boiling water that rise in the valley of Rykum. It now remains for me to send you a description of those we visited in the neighbourhood of Haukadal.

These last are the most remarkable in the island, and the eruptions of water from some of them so

astonishing, that I doubt whether any adequate idea of their effect can be given by description. Abler pens than mine might fail probably in attempting to do justice to such wonderful phenomena. The objects, however, are so highly interesting in themselves, that even the simplest narrative that can be given of them will be read with more than ordinary attention.

They are situated about six and thirty miles from Mount Hecla, and about twelve miles, in a north-east direction, from the village of Skalholt.* The road from thence to the springs is over a flat country, which, although marshy in several places, is not unpleasant to the eye, and abounds in excellent pasture.

The steam ascending from the principal springs during their eruptions may be seen from a considerable distance. When the air is still, it rises perpendicu-

* Skalholt consists of the Cathedral, a large building of wood, and of a very few houses belonging to the Bishop and his dependants. The Bishops of the southern division of Iceland have always resided there; but in future their residence will be at Rykiavick, a town now building on the south-west coast of the island. The present Bishop, however, the worthy and learned Mr. FINNOK, has obtained the permission of continuing his residence at Skalholt during the remainder of his life.

larly, like a column, to a great height; then spreads itself into clouds, which roll in successive masses over each other, until they are lost in the atmosphere. We perceived one of these columns, when distant sixteen miles at least, in a direct line from Haukadal.

The springs mostly rise in a plain, between a river that winds through it, and the base of a range of low hills. Many, however, break out from the sides of the hills, and some very near their summits. They are all contained, to the number of one hundred or more, within a circle of two miles.

The most remarkable spring rises nearly in the midst of the other springs, close to the hills. It is called Geyzer;* the name probably in the old Scandinavian language for a fountain, from the verb *geysa*, signifying *to gush*, or *to rush forth*. The next most remarkable spring rises at a distance of one hundred and forty yards from it, on the same line, at the foot of the hills. We called it the New Geyzer, on account of its having but lately played so violently as at present.

* Three or four only of the principal springs in Iceland are distinguished by the name of Geyzer, and of all the springs near Haukadal the greatest is alone called Geyzer, or Great Geyzer.

There are others of consequence in the place, but none that approach to these in magnificence, or that when compared with them, deserve much description. The generality of the springs are in every respect similar to those near Rykum; boiling in caldrons of three or four feet diameter, and some of them throwing their water from time to time, by sudden jets, into the air. Many springs in this place, as in the other, boil through strata of coloured clay, by which they are rendered turbid. Here, however, the red clays were brighter, and in a greater proportion to the clays of other colours. Here also, as in the valley of Rykum, are many small springs, which throw out sulphureous vapour, and near which the ground, and the channel of the water, are covered and lined with a thin coat of sulphur.

The farm of Haukadal, and the church of the parish, stand near to each other about three quarters of a mile beyond the great spring. The house is one of the best built in Iceland. It occupies a large space of ground, and consists of several divisions, to each of which there is an entrance from without. Some of these are used as barns and stables for the cattle, and

others as work-shops.* The dwelling part of this house was small but comfortable. There was a parlour with glass windows, a kitchen, and separate bedchambers for the family. The building was partly of stone, partly of wood, and covered with sods, under which the bark of birch trees on boards was placed, as a greater security against rain.

We were obliged to the mistress of this farm, who was a rich widow, for a very hospitable reception, altho' at first she seemed to consider us as rather unwelcome visitors, and left us, though we had requested admittance into her house, (as we were drenched with rain, and our tents and baggage not yet arrived) to take up our lodging in the church. We had not been long there, however, before she invited us to her house, and by her kindness made ample amends for her former inattention. She put us in possession of her best room, and set before us plenty of good cream, some wheat

* As the division of labour is yet very imperfect in Iceland, the farmer is under the necessity either of exercising himself the several trades required in the formation of the instruments of agriculture, or of maintaining such servants as are capable to supply them.

cakes, sugar, and a kind of tea made of the leaves of the *dryas octopetala*.*

I mention these circumstances of our reception at Haukadal, as characteristic of the manners of the Icelanders. Several times during my stay in the country, I experienced this succession of civility to coldness. The Icelanders are naturally good, but not easily roused to feeling. When once their constitutional indifference was overcome, we usually found them desirous of pleasing, and zealous to do us service.

As the house was not sufficiently large to contain the whole of our party, we were under the necessity of returning again to the church, as soon as our baggage arrived. Here we passed the first and second nights of our stay, in the neighbourhood of the springs. On the third day we left Haukadal, to fix ourselves in some station nearer to them, from which we could watch their eruptions with more convenience.

* Called in English the Mountain Avens. We found this plant growing very luxuriantly, and in great abundance, in every part of Iceland that we visited.

The view from near the church was very beautiful. It extended toward the south along the plain into an open country. On the other side, it was bounded by hills, which had not the barren and rugged appearance that deform almost every scene in this division of the island. It was, however, still finer from some of the eminences near the springs. The plain and the surrounding mountains, seen from a height, appeared to more advantage; and the eruptions from the great wells breaking from time to time, the general stillness that prevailed, were much more distinct. The course of the river winding under the eye, could be traced with greater accuracy. It flows through the plain into an open country, where, being increased by the waters of numerous streams and rivulets, it bends to the westward, and near Skalholt falls into a considerable river, the Huit-aa.

The pleasant and fertile pastures near its banks were enlivened by numerous herds of cattle and sheep, the united riches of three or four farmers in the neighbourhood of Haukadal. The mowers also at work in the different fields surrounding each house, gave, at this season, additional beauty to the prospect. High hills to the westward were separated from the eminencies

immediately above the springs, by a narrow valley. They were partly clothed with bushes of birch, which although in no place above five feet high, were gratifying to the sight, which so seldom in Iceland can rest on any appearance even of underwood. Above these, some vegetation still continued to cover the sides of the hills, and Mr. WRIGHT found a variety of plants* near their summits, which were certainly, in some places, not less than 1600 feet above the plain.

To the eastward, the plain, several miles in breadth, was bounded by a long range of blue mountains, extending considerably to the south. Beyond these, the triple summit of Hecla may be seen from the western hills; but I could not distinguish it from the plain, or even from the heights whence the view of the surrounding country was taken, which I am now describing.

To the north behind Haukadal, there were many high mountains, but at a great distance, and of which

* Amongst others, he found the *salix herbacea* (teft willow), the *ceraifium tomentosum* (woolly mouse ear chickweed), the *rumex dignus* (round leaved mountain sorrel), and the *koenigia*, (a plant peculiar to Iceland), growing in great abundance, though generally in low and marshy grounds.

the most distant were covered with snow. They formed part of a dreary assemblage of *Jokuls* or ice-mountains, which occupy a considerable extent of the interior country. Their forms were mostly conical; and from their general resemblance to other mountains in the island, from which streams of lava have been emitted, I think it probable they were once volcanos. They are not so connected as to form a continued range or chain of hills. Each stands insulated; and therefore the snows which have for ages rested on their sides, are no where accumulated in valleys, and converted into lakes of ice and glaciers, as amidst the Alps of Switzerland and Savoy.

A view so different from the general features of the country, impressed us with the most agreeable sensations. Hitherto we could but compare one scene of dreariness with another; and although the view before us was destitute of trees, yet the verdure, and pleasant distribution of hills and plain, in some measure compensated for this deficiency.

I now return to the account of the springs, which I have already observed break out in different places from the sides of a hill, and the space inclosed be-

tween its base and the windings of a river. The soil through which they rise is a mixture of crumbled materials, washed by degrees from the higher parts of the hill. In some places, these have been reduced into a clay or earth; in others, they still remain loose and broken fragments of the rocks from whence they have fallen, or a dust produced by their friction against each other. Wherever the ground is penetrated by the steam of the springs, these fragments are soon decomposed, or changed into coloured clays. In other places, the surface of the ground is covered with incrustations deposited by the springs, or with a luxuriant vegetation of grass or dwarf bushes of willow and birch, and the *empetrum nigrum*,* the berries of which were at this time ripe and in great abundance.

Above the great spring, the hill terminates in a double pointed rock, which Mr. BAINE found by measurement to be 310 feet higher than the course of the river. The rock is split very strangely into lamina, and at first sight has much the appearance of a schistus, or

* The crow berry. This is almost the only fruit we met with in Iceland. Mr. WRIGHT found a few strawberries. Neither gooseberries nor currants will come to perfection by any management whatever.

bed of thick slate. It consists, however, of a grey coloured stone of a very close grain, the separate pieces of which, although divided as they lay, do not break in the hand in any particular direction. I should suppose the substance of this rock to be chiefly argillaceous, and that, like every other stone in the island, it has suffered some change by the action of fire. I do not mean to call it lava, as it bears no mark of having been once in a melted state, whatever baking or induration it may have sustained in the neighbourhood of subterraneous heat. It contains no heterogeneous matter, or cavities, in which agates, or zeolites, or vitrified substances of any kind, could have been formed.

All these rocks that have been either altered or created by fire, seem much more liable to decay and decomposition than any others I have ever seen.— Mounds, similar to those in the valley of Rykum, have been formed by the ruins of the hill half way up its ascent, between the Geyser and the pointed rock. Springs boil in many places through these mounds, and near to one of them, I observed that the coloured clay felt much more soapy than any I had tried before.— This quality probably was owing to a greater propor-

tion of the earth of magnesia in its composition, as in other respects it agreed perfectly with the rest.

My attention, during the four days I remained in this place, was so much engaged by the beauties and remarkable circumstances of the two principal springs, that I cannot (were I so inclined) give you a minute account of those which, next to them, were deserving of notice. The springs in general resemble those at Rykum; but there are five or six which have their peculiarities, and throw up their waters with violence to a considerable height. Their basins are of irregular forms, four, five, or six feet in diameter, and from some of them the water rushes out in all directions, from others obliquely. The eruptions are never of long duration, and the intervals are from 15 to 30 minutes. The periods of both were exceedingly variable. One of the most remarkable of these springs threw out a great quantity of water, and from its continual noise we named it the Roaring Geyzer. The eruptions of this fountain were incessant. The water darted out with fury every four or five minutes, and covered a great space of ground with the matter it deposited. The jets were from thirty to forty feet in height. They were shivered into the finest particles of spray, and sur-

rounded by great clouds of steam. The situation of this spring was eighty yards distant from the Geyzer, on the rise of the hill.

I shall now, Sir, attempt some description of this celebrated fountain, distinguished by the appellation of Geyzer alone, from the pre-eminence it holds over all the natural phenomena of this kind in Iceland.

By a gradual deposition of the substances dissolved in its water for a long succession of years, perhaps for ages, a mound about thirty feet high has been formed, from the centre of which the Geyzer issues. It rises through a perpendicular and cylindrical pipe, or shaft, sixty-one feet in depth, and eight feet and a half in diameter, which opens into a basin or funnel, measuring fifty-nine feet from one edge of it to the other.—The basin is circular, and the sides of it, as well as those of the pipe, are polished smooth by the continual friction of the water, and they are both formed with such mathematical truth, as to appear constructed by art. The declivity of the mound begins immediately from the borders of the basin. The incrustations are in some places worn smooth by the overflowing of the water; in most, however, they rise in numberless

little tufts, which bear a resemblance to the heads of cauliflowers, except that they are rather more prominent, and are covered, by the falling of the finer particles of spray, with a crystalline efflorescence so delicate as scarcely to bear the slightest touch. Unmolested, the efflorescence gradually hardens, and although it loses its first delicacy, it still remains exceedingly beautiful.

These incrustations are of a light brown colour, and extend a great way, in various directions, from the borders of the basin. To the northward they reach to a distance of 82 feet; to the east, of 86; to the south, of 118; and of 124 to the west. They are very hard, and do not appear, in any part, decaying, or moulder ing into soil.*

* The substance of these incrustations has been analysed by Professor BEROMAN, and he gives a long and particular account of it in a letter to the Archbishop of Upsal, published with the Archbishop's Letters on Iceland. He says, "The strongest acids, the fluor acid "not excepted, are not sufficient, with a boiling heat, to dissolve "this substance. It dissolves very little (if at all) by the blow pipe, "with the fusible salt of urine, a little more with borax, and makes "a strong effervescence with sal soda. These effects are peculiar "only to a siliceous earth or flint. There cannot remain therefore "a doubt concerning the nature of this crustated stone."

When our guides first led us to the Geyzer, the basin was filled to within a few feet of its edge. The water was transparent as crystal; a slight steam only arose from it, and the surface was ruffled but by a few bubbles, which now and then came from the bottom of the pipe. We waited with anxiety for several minutes, expecting at every instant some interruption to this tranquillity. On a sudden, another spring, immediately in front of the place on which we were standing, darted its waters above an hundred feet into the air with the velocity of an arrow, and the jets succeeding this first eruption were still higher. This was the spring already mentioned under the name of the New Geyzer.

While gazing in silence and wonder at this unexpected and beautiful display, we were alarmed by a sudden shock of the ground under our feet, accompanied with a hollow noise, not unlike the distant firing of cannon. Another shock soon followed, and we observed the water in the basin to be much agitated. The Icelanders hastily laid hold of us, and forced us to retreat some yards. The water in the mean time boiled violently, and heaved as if some expansive power were labouring beneath its weight, and some of it was thrown

up a few feet above the bafon. Again there were two or three shocks of the ground, and a repetition of the same noise. In an instant the surrounding atmosphere was filled with volumes of steam rolling over each other as they ascended, in a manner inexpressibly beautiful, and through which, columns of water, shivering into foam, darted in rapid succession to heights which, at the time, we were little qualified to estimate. Indeed, the novelty and splendour of such a scene had affected our imaginations so forcibly, that we believed the extreme height of the jet to be much greater than it was afterwards determined to be. In a subsequent eruption, Mr. BAINE ascertained, by means of a quadrant, the greatest elevation to which the jets of water were thrown, to be 96 feet.

Much of the water began to descend again at different heights, and was again projected by other columns, which met it as they rose. At last, having filled the bafon, it rolled in great waves over its edge, and forming numberless rills, made its way down the sides of the mound. Much was lost in vapour also, and still more fell to the ground in heavy showers of spray. The intervals at which the several jets succeeded each other, were too short for them to be distinguished by the eye

As they rose out of the basin, they reflected, by their density, the purest and most brilliant blue. In certain shades, the colour was green, like that of the sea; but in their further ascent, all distinction of colour was lost, and the jets, broken into a thousand parts, appeared white as snow. Several of them were forced upwards perpendicularly; but many, receiving a slight inclination as they burst from the basin, were projected in beautiful curves, and the spray which fell from them, caught by a succeeding jet, was hurried away still higher than it had been perhaps before.

The jets were made with inconceivable velocity, and those which escaped uninterrupted terminated in sharp points, and lost themselves in the air. The eruption, changing its form at every instant, and blending variously with the clouds of steam that surrounded it, continued for ten or twelve minutes; the water then subsided through the pipe, and disappeared.

The eruptions of the Geyser succeeded each other with some degree of regularity, but they were not equally violent, or of equal duration. Some lasted scarcely eight or ten, while others continued, with unabated violence, fifteen or eighteen minutes. Between the great erup-

tions, while the pipe and basin were filling, the water burst several times into the air to a considerable height. These partial jets, however, seldom exceeded a minute, and sometimes not a few seconds, in duration.

After the eruption of it had been violent, the water sunk into subterraneous caverns, and left the pipe empty. If the eruption had been moderate, the subsidence of the water was proportionably less. The first time the pipe was perfectly emptied, we sounded its depth, and found the bottom very rough and irregular. The pipe remained but a short time empty. After a few seconds, the water rushed into it again with a bubbling noise, and during the time that it was rising in the pipe, it frequently darted suddenly into the air to different heights, sometimes to two or three, sometimes sixty feet above the sides of the basin. By a surprise of this kind, while we were engaged measuring the diameter of the well, we had nearly been scalded ; and although we were able to withdraw ourselves from the great body of water as it ascended, yet we remained exposed to the falling spray, which fortunately was so much cooled in the air as to do us no mischief.

Of these jets we counted twenty in an hour and an half, during which the waters had filled the pipe, and in part the bafon. It then seemed oftentimes agitated, and boiled with great violence. The jets were more beautiful, and continued longer, as the quantity of water in the bafon increased. The resistance being greater, their force was in some degree broken, and their form, more divided, produced a greater display of foam and vapour.

While the pipe was filling, we threw into it several stones of considerable weight, which, whenever the water burst forth with any violence, were projected much higher than itself. These stones in falling were met by other columns of water, and amidst these they rose and fell repeatedly. They were easily distinguished amidst the white foam, and contributed much to the novelty and beauty of this extraordinary phenomenon.

When the bafon was nearly full, these occasional eruptions were generally announced by shocks of the ground, similar to those preceding the great eruptions. Immediately after the shocks, the whole body of water in the bafon heaved exceedingly; a violent ebullition then took place, and large waves spread themselves in

circles from the centre, through which the column forced its way.

When the water had been quiet in the basin for some time, the thermometer placed in it stood at 180° only, but immediately after an eruption it rose to 200° . We boiled a piece of salmon in it, which tasted exceedingly well, not being in the least tainted with sulphur. Our cookery at Rykum had not been quite so successful.

The water thrown out from the Geyzer is joined at the bottom of the mound by that which flows from the spring called the Roaring Geyzer, formerly described. The stream produced by their united waters flows three or four hundred paces before it falls into the river, where its temperature is reduced to 72° . Even at this place is deposited much of the substances it contained; but during the whole of its course, the plants growing on its banks were covered with beautiful incrustations. Some of these we wished to preserve, but from their extreme delicacy they fell into pieces on every attempt to remove them.

The situation of the New Geyzer* is in the same line from the foot of the hill with the Great Geyzer. Its pipe is formed with equal regularity, and is six feet in diameter, and forty-six feet ten inches in depth. It does not open into a basin, but it is nearly surrounded by a rim or wall two feet high. After each eruption, the pipe is emptied, and the water returns gradually into it, as into that of the Old Geyzer. During three hours nearly that the pipe is filling, the partial eruptions happen seldom, and do not rise very high; but the water boils the whole time, and often with great violence. The temperature of the waters after one of these eruptions, was constantly found to be 212° . Few

* Before the month of June, 1789, the year I visited Iceland, this spring had not played with any great degree of violence, at least for a considerable time. (Indeed the formation of the pipe will not allow us to suppose, that its eruptions had at no former period been violent). But in the month of June, this quarter of Iceland had suffered some very severe shocks of an earthquake; and it is not unlikely, that many of the cavities communicating with the bottom of the pipe had been then enlarged, and new sources of water opened into them. The difference between the eruptions of this fountain, and those of the Great Geyzer, may be accounted for from the circumstance of there being no basin over the pipe of the first, in which any water can be contained to interrupt the column as it rises. I should here state, that we could not discover any correspondence between the eruptions of the different springs.

incrustations are formed round this spring, excepting in the channel where the water flows from it.

The great eruption is not preceded by any noise, like that of the Great Geyzer. The water boils suddenly, or is heaved over the sides of the pipe; then subsiding a little, it bursts into the air with inconceivable violence. The column of water remains entire, until it reaches its extreme height, where it is shivered into the finest particles. Its direction was perpendicular, and greatest elevation 132 feet. Like the eruption of the Old Geyzer, this consisted of several jets, succeeding each other with great rapidity. Whatever we threw into the well was hurled into the air with such swiftness that the eye could scarcely discern it,* and the division of the water at the extremity of the column was so minute, that the showers of spray which fell were cold. Towards the end of an eruption, when more steam than water rushed from the pipe, I ventured to hold my hand near the edge of the column, in the way of some of the divided particles of water, and found them tepid only.

* Mr. BAINE measured the height to which a stone was thrown by one of these jets, and found it 129 feet. Some others rose considerably higher.

You may probably think this a rash experiment, and certainly it was so. But we had made our observations on the uniform direction of the column, and confided our safety in it. Once or twice, however, we had reason to think ourselves more fortunate in escaping, than prudent in avoiding, the danger which attended a too near approach to these eruptions of boiling water. During ten or fifteen minutes, the water continued to be thrown upwards with undiminished impetuosity. At the end of that period the quantity became less, and at length, ceasing entirely, steam alone ascended. In one instance the eruption continued thirty minutes. It seldom, however, exceeded twenty, and sometimes was completed in fifteen minutes. The force with which the steam rises abates as the water sinks in the pipe, and when this is exhausted, that soon disappears.

I have now, Sir, given you such a description of these celebrated fountains as was in my power. I hope that it will afford you some satisfaction, and I could wish that it might serve as an inducement to some curious inquirer into the history of nature to visit them, who shall have all the knowledge requisite for making

such observations as are yet to be desired concerning them. I cannot flatter myself, that the description I have attempted of their eruptions will impress you with a just idea of their beauty. Sources of comparison are wanting, by which the portraiture of such extraordinary scenes can be assisted. Nature no where offers objects bearing a resemblance to them; and art, even in constructing the water-works of Versailles, has produced nothing that can at all illustrate the magnificent appearances of the Geyser. All then that I hope for is, to have said so much as may enable you to complete in your imagination, the picture which I have only sketched. Imagination alone can supply the noise and motion which accompany such large bodies of water bursting from their confinement; and must be left to paint, what I have not been able to describe, the brilliancy of colouring, the purity of the spray, the quick change of effect, and the thousand varieties of form into which the clouds of steam, filling the atmosphere on every side, are rolled incessantly.

I have avoided entering into any theory of the cause of these phenomena, that you may not suppose the account I give you has been biased by a favourite hypo-

thesis. I have given you an accurate state of facts, and I leave to you the explanation of them. There cannot, however, be two opinions concerning the immediate cause which forces the water upwards. It is obviously the elasticity of steam endeavouring to free itself. In addition to this, the form of the cylinder through which the water rises, gives it that projectile force which carries it so high. Beyond this, it would not become me to hazard any opinion.

Of the antiquity of these springs I can say nothing, further than that they are mentioned as throwing up their waters to a great height by SAXO GRAMMATI-CUS, in the Preface to his History of Denmark, which was written in the twelfth century; but from the general features of the country, it is likely, that they have existed a great length of time. The operations of subterraneous heat seem indeed to be of great antiquity in Iceland, and the whole country probably owes its existence to the fires which burn beneath its surface. Every hill proves, at least, with what violence these fires have acted for ages; and the terrible eruptions of Java, which burst from the mountains of Skapte-

field, in 1783, shew that they are as yet far from being extinguished.

I am,

Dear Sir,

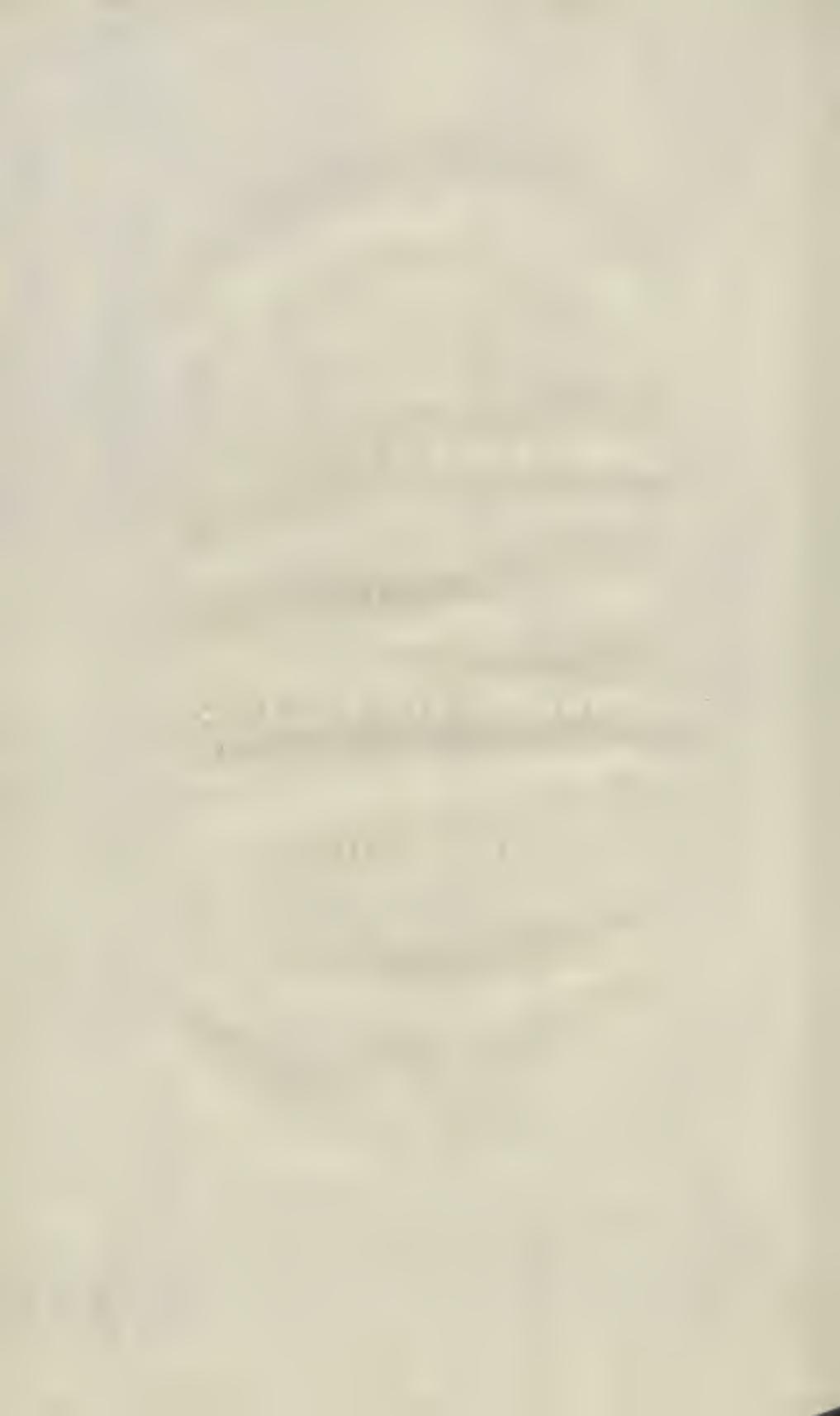
With great regard and esteem,

Your very obedient servant,

JOHN THO. STANLEY.

AN
ANALYSIS
OF THE
Waters
OF SOME
HOT SPRINGS
IN
ICELAND.

By JOSEPH BLACK, M.D. &c. &c.



*An Analysis of the Waters of some Hot Springs
in ICELAND.* By JOSEPH BLACK, M. D. Professor
of Medicine and Chemistry in the University of Edin-
burgh; First Physician to his Majesty for Scotland,
Fellow of the Royal Collège of Physicians, and of the
Royal Society of Edinburgh; Member of the Academy of
Sciences, and of the Society of Medicine of Paris, of
the Imperial Academy of Peterburgh, &c. &c.

[Read July 4, 1791.]

SIR JOSEPH BANKS, to whose indefatigable ardour
for the advancement of natural history, the philosophi-
cal world is so much indebted, made a voyage to Ice-
land in the year 1772, to inquire into the productions
of that remote part of the world, and particularly into
those of its famous volcano. When he returned, he

brought from thence, among many other natural productions, some petrified vegetables, and incrustations, formed by the waters of the boiling springs; and he was so good as to present a part of them to his friends here, who were surprised to find them composed of siliceous earth. As this was the first example observed of water containing this earth in such quantity as to form siliceous petrifactions, it raised a strong desire to have an opportunity of examining the water, and of learning by what means this siliceous matter was dissolved in it; and this opportunity was at last given us by JOHN THOMAS STANLEY, Esq. who, excited by motives similar to those of Sir JOSEPH BANKS, equipped likewise a vessel, and made a voyage to Iceland, during the summer 1789. He brought from thence, and from the Faro Islands, a number of fine specimens of volcanic and other fossil productions, and along with them, a quantity of the water of the two most remarkable boiling and exploding springs of Iceland, called by the natives *Geyzer* and *Rykum*; and having favoured me with a portion of these waters, and expressed his desire that I would examine them, I have accordingly made a number of experiments with them, an account of which I shall now submit to the Society. If the detail of it should appear tedious; if I shall be thought to

have given much attention to very small matters, it must be considered, that the nature of the subject requires exactness. The quantities of the materials which are to be examined in such experiments, are but small, though it often happens, that these small quantities of matter, acting in nature for a great length of time, produce accumulations, and other effects, that appear very surprising and worthy of attention. I must also confess, that I took pleasure in promoting, as far as I could, the information concerning Iceland, which the philosophical zeal and spirit of the Gentlemen I mentioned, have procured for us.

Both these waters had a weak smell of the Hepatic Gas, or a small degree of the odour, which is well known in Harrowgate, and other sulphureous waters. The quantity, however, of this sulphureous matter in them was so very small, that I was not able, by any experiments, to obtain it in a separate state, or bring it into view in any form whatever. I therefore could not make any attempt to estimate the quantity of it.

Those who are acquainted with sulphureous waters, know that an incredibly small quantity of their volatile sulphureous matter is sufficient to give a perceptible

colour; and it is so liable to be decompounded and changed, while we attempt to separate it from water, that such an attempt never succeeds when the quantity of it is final. There was also reason to believe, that some part of it had already been lost or changed during the voyage, this matter being one of those volatile ingredients of mineral waters, which are the most liable to be evaporated or changed by the action of the air, and other causes. I therefore think it sufficient to mention, that these waters contained a small quantity of this substance.

I began by making a few preliminary trials, to acquire some notion of the nature of these waters.

1. An equal quantity of lime-water being added to the Iceland waters, there was a little diminution of transparency, but only in the smallest degree, and no sediment was formed.

2. Mild volatile alkali produced no effect whatever.

3. Paper stained blue with the March violet, being dipped into the water and dried, had its colour changed a little towards a green.

4. Cambric stained to a blueish purple, with infusion of litmus, assumed a more perfect blue colour, when dipped into the water and dried.

5. Acid of sugar did not produce a perceptible muddiness or precipitation.

6. Nor did the solution of corrosive sublimate.

7. The solution of sal saturni (plumbum acetatum) made the water very muddy, and white, but a small quantity of distilled vinegar re-dissolved nearly the whole of the precipitate, and made the water almost perfectly clear again.

8. The solution of barytes in muriatic acid made the water become muddy, and deposit a sediment, which was not re-dissolved by adding purified nitric acid.

9. The solution of silver produced a strong muddiness, and considerable precipitation, which was not re-dissolved by adding purified nitric acid.

The last trial shewed the presence of the muriatic acid, and the one preceding it, that of the vitriolic acid in the composition of these waters; but by the 3d, 4th, and 7th, I also learned, that there was more than enough of alkaline matter to saturate both of them. The 5th trial shewed that the alkaline matter was not calcareous earth, but alkaline salt; and the 6th, that this alkaline salt was not the volatile, but one of the fixed alkalis. The 1st trial shewed, that this unsaturated fixed alkali was not combined with air, or that if any was combined with it, the quantity was so small as to be scarcely perceptible.

None of these trials gave any indication of the earthy matter contained in these waters; and as my principal object was to investigate the nature of their petrifying power, I now began with the following experiment:

Evaporation of the Water.

I evaporated 10,000 grains weight of each of these waters to dryness with a gentle heat, in separate glasses. The dry extract of the water of Rykum weighed gr. 8.25, and that of Geyzer, gr. 10.

The evaporation was performed in cylindrical glass vessels, about 3 inches wide and $7\frac{1}{3}$ deep, which received heat from the steam of boiling water, not directly, but through the intervention of white-iron casings, which fitted the glasses, and in which they hung; I have often used this apparatus in examining and comparing different waters; and the advantages of it are, that the greater part of the fixed matter is collected on a small surface; that the glasses are so moderately heated, that they bear water to be added, during the evaporation, without danger of breaking; and lastly, when the whole water is evaporated, the fixed matter, while it is thoroughly dried, by leaving it exposed some hours to the heat, never becomes so hot as to suffer the loss of any part of the acid of the saline compounds which it may contain, and when it is dry, the quantity of it is accurately determined, by weighing it in the glass, the weight of which can be ascertained, both before the water is put into it, and after the extract is taken out.

In the end of these evaporation of the Iceland waters, they emitted an odour similar to that of alkaline leys, which contain an alkali not very pure or well calcined, and afterwards, when the evaporation was nearly completed, the residuum assumed the form of

a transparent jelly, which had nearly the thickness of half a crown. This jelly afterwards became divided by fissures, into a great number of small portions, which, in drying, contracted their size, and greatly widened the fissures, forming at last a number of small fragments of white crust, unconnected with one another, and not adhering to the bottom of the glass. A small quantity only of this matter attached itself to the sides of the glass during the evaporation, and formed there circles of an exceeding thin incrustation, which adhered strongly, and required much patience to scrape it off with a knife.

These phenomena are exactly similar to those which appear in evaporating water which contains siliceous earth, dissolved in it artificially by means of an alkaline salt. The colour of the dry matter obtained from Ry-kum water was almost a pure white; that of the water of Geyzer was a yellowish white.

While these dry extracts were kept for some time in the glasses, placed in a cold room, in the winter season, they attracted humidity, and the extract of Geyzer attracted the most. Eight grains of the extract of Ry-kum attracted in one week four grains of humidity; the

fame quantity of the extract of Geyzer attracted in the fame time ten grains of humidity. My attention, however, was turned for some time from these experiments; but resuming them again after some months, I found that these extracts remaining in the same glasses, and in the same room, had again become dry, and had lost the greater part of the weight which they had acquired at first by attracting humidity. This I imputed partly to the state of the atmosphere, and partly to their having attracted fixed air, by their union with which they had lost their strong attraction for water.

The constituent parts of these extracts were next to be investigated. I soon perceived that they contained a portion of alkaline salt not saturated with acid, which became evident when a small quantity of them was wetted and applied to paper stained with the juice of violets, or the colouring matter of the common purple radish; the colour in either case was changed to a green. I further collected and scraped these extracts out of the glasses, and placing each in a small filtré, I dropped distilled water on them repeatedly, until the water came away from them insipid. The waters which had been thus filtrated through them were put into china cups, and the greater part evaporated with a gentle heat, the

rest was allowed to evaporate spontaneously in a dry room. Thus, a number of small saline crystals were formed, which were partly regular crystals of common salt, and partly crystals of an oblong and flattened form, larger than those of the common salt. These larger crystals were distinguishable, not only by their form, but by some of their properties. They became white, opaque, and mealy in dry air, and being taken out, and tasted and tried in different ways, were found to contain some of the fossil alkali in a crystallized state.

The undissolved matter which had remained on the filtrating paper, appeared by its properties to be totally or principally made up of filiceous earth. It was white and exceedingly spungy and light. A small portion of it was triturated, and made into a paste with water; which paste being laid on a piece of charcoal and dried, was heated intensely with the blowpipe. No part of it was melted; it was only contracted in its dimensions, and acquired a weak degree of cohesion. Another small portion was triturated dry, with an equal weight of aerated and exsiccated fossil alkali; and being put into a small platina spoon, against the bottom of which the flame of the blowpipe was strongly directed, the mixture was soon melted into a transparent

colourless glass, which afterwards, by being digested, with a small quantity of distilled water, was completely dissolved, and formed a liquor which had all the qualities of the *liquor silicum*.

I need not take notice here of the quantity of the earth, and saline matter which were in some measure separated from one another in this experiment. I had reason to suspect, that neither of them were obtained in this way without some loss. The odour emitted by the water in the end of evaporation, gave reason to suspect the loss of some part of the salts; and it was probable that a part of the earth would remain combined with the alkali, in a soluble state, in the dry extract, and would pass through the filter, when I dissolved and washed away the saline matter.

I therefore planned a set of experiments, by which the quantity of each ingredient in these waters might be more certainly known: and began with the following

*Experiments to investigate the Quantity of the un-neu-
tralized alkaline Salt.*

In making the experiments to decide this question, I made use of an acid, which I had often employed before in experiments, to learn the quantity of pure or caustic alkali, contained in aerated alkalis, and in various barillas, kelps, and other such heterogeneous masses. This acid was a quantity of the vitriolic, the power of which, in saturating pure alkalis, I had carefully examined, and I was accustomed to add it very gradually to filtrated solutions of the above substances, until they were exactly saturated; and then, from the quantity of acid required to produce the effect, I learned the quantity of un-neutralized alkali which these substances contained. The specific gravity of this vitriolic acid, compared with that of water, was as 1793 to 1000, in a temperature of heat equal to 60 of FARENHEIT. When I had used it on former occasions, I diluted some of it, with four times its weight of distilled water, and used this mixture in place of the pure acid, that I might the more readily portion it into small doses; but on this occasion, I made a mixture of it, with about 100 times its weight of distilled water;

and effaying this mixture afterwards, with great attention, I found that 112 grains of it saturated one grain of the pure alkaline part of the alkali of tartar, and 171.55 grains were required for the saturation of one grain of the pure, or caustic part of the fossil alkali.

With this largely-diluted acid, the strength of which was thus ascertained, I began to investigate the quantity of alkali in the Iceland waters. I gave a pale purple, or blue colour to a portion of the Rykum water, by adding a few drops of an infusion of litmus, the bluish purple of which became more blue when mixed with this alkaline water, and I began to add, very gradually, some of the largely-diluted vitriolic acid, expecting to see the colour change to a reddish purple, when the alkali became completely saturated. This method, however, did not succeed so well as I had supposed; for although I changed the colour to a reddish purple, or even to a pure red, by adding an exceeding small quantity of the diluted acid, the red thus produced was not permanent. Next day, I found it returned again to the blue, and requiring a new addition of acid; and this happened so often, after repeated additions of acid, that this process appeared very tedious, and scarcely capable of being brought to a pre-

cise limit; for in proportion as I continued the process the longer time, or had made the more numerous additions of acid, the time necessary for the return of the colour from red to blue was always the longer, and at last was no less than several weeks.

These phenomena appear to me to have proceeded from the very weak and slow action of the acid and alkali on one another, in consequence of the excessively-diluted state in which they were mixed together, the alkali at the same time not being pure, but combined with the siliceous earth, a substance for which it has a considerable attraction. I therefore supposed, that when I added the small doses of diluted acid, the acid particles remained for some time dispersed through the liquor, without joining the alkali, and the water contained, at the same time, a silicated alkali, if I may so call it, and an unsaturated acid; but the colour of litmus being much more disposed to be affected and changed by acids than alkalies, it became red, and retained this colour as long as any particles of the acid remained unsaturated. These, however, after some time, being all attracted and saturated by the alkali, the colour was again changed by the remaining unsaturated alkali.

It may, perhaps, be suspected, that a small quantity of fixed air, detached from the alkali, might be the cause of this temporary red colour, and that the colour returned again to blue, when the fixed air evaporated from the water; and I know, that a very small quantity of fixed air contained in water, is sufficient to change the colour of litmus, and that a considerable time is required for its evaporation from the water; so that the litmus may recover its natural tint: but it is equally true, that the fixed air never requires so long a time for its evaporation as several weeks, and that it has not the power to redden litmus, when an alkali is present, except when the quantity of the alkali is exceedingly small, and that of the fixed air incomparably more than sufficient for saturating the alkali. In the present case, the last of these conditions never could take place, the quantity of acid added at once being far too small to detach enough of air, even although the alkali had been originally saturated with air, which it certainly was not; it appeared rather to be in a caustic state, or very nearly caustic. This reasoning suggested to me another mode of making the experiment, which succeeded perfectly in a moderate time.

The foregoing experiments, and others which I made with small quantities of the water, enabled me to form some judgment of the proportion of acid necessary to saturate the alkali which this water contained. I therefore added to 10,000 grains of the Rykum water, 200 grains, accurately weighed, of the largely-diluted vitriolic acid; which quantity I judged to be considerably more than sufficient for saturating the alkali of this water; and after the acid was poured in, the small and light glass in which it was weighed was rinsed several times with distilled water, which was added to the Rykum water. I also gave it a pale tincture with some drops of the infusion of litmus, and then boiled the water gently in a thin-bottomed glass, until it was reduced to one fourth of its first quantity. It still continued of a red colour, without the least tendency to a purplish hue, and shewed that the acid was more than enough to saturate the alkali.

It was necessary, in the next place, to learn with certainty, how much of the acid had been superfluous. With this intention, I added a largely-diluted solution of alkali of tartar in distilled water. In this solution, the pure alkali, considered as distinct from the air which was joined to it, constituted one fortieth part of the weight of the fluid. I weighed 38.6 grains of this fa-

lution; which quantity I knew, by the previous experiments, was exactly, or nearly sufficient for saturating the superfluous acid. I poured it at once into the hot water, and rinsing the small and light glass in which it was weighed two or three times with distilled water, I poured in this also. A little effervescence appeared in the hot water; I therefore set it again on the furnace to boil, that the fixed air might be expelled, and I added now and then a little distilled water, to prevent it from boiling down too much. In less than half an hour's boiling, the fixed air being all expelled, the colour changed from red to purple, with a very small tendency towards the red. This shewed that the quantity of salt of tartar, which had been added, was exactly sufficient for saturating the superfluous acid. Had the saturation not been sufficiently exact, I could have added a little more of the alkali, or a little more of the acid, as I had done in the smaller essays which were preparatory to this; but the tint of colour which I had here produced, was that which I had found to be the most discernible and satisfactory sign of exact saturation, in former experiments; and it is proper to mention, that one grain more of the largely-diluted vitriolic acid changed this purple, very remarkably, to a more decided red, and that with one grain less, the hue of

the purple, by being inclined to blue, would have been equally distinguishable; of which I satisfied myself, by adding as much of the solution of salt of tartar as saturated one grain weight of the largely-diluted acid.

The quantity of the diluted acid added at first was 200 grains. From this was to be subtracted 108.32 grains, the quantity saturated by the 38.6 grains of the solution of salt of tartar; the remainder is gr. 91.68. From this quantity, however, we must make another deduction; for, as Professor BERGMAN justly observed, the infusion of litmus contains something which is of an alkaline nature, or is capable of saturating a certain quantity of acid. To learn how much was to be deducted on this account, I tinged a small quantity of distilled water, with the same number of drops of the infusion of litmus that I had used in tinging the Iceland water, and then making the distilled water boiling hot, I began to add some of the largely-diluted vitriolic acid, and kept the water boiling all the time. The first additions of acid, as I expected, did not produce a change of colour, or, if any change was produced, it soon disappeared again, while the water was boiling; but as soon as I had added gr. 3.5, a permanent change was produced to a reddish purple. This quantity therefore

must, in the next place, be deducted from the gr. 91.68, and thus we have gr. 88.18, as the quantity of the diluted vitriolic acid which was employed solely in saturating the alkali of the water. But from the essays I had made of the power of this diluted acid in saturating alkalis, it is evident that this quantity of it was sufficient for saturating gr. 0.514 of the pure, or caustic fofil alkali, or gr. 0.857 of that which is saturated with air, and evaporated to dryness, or about gr. 2.38 of that which is saturated with air, and in form of transparent crystals.

The next step was to make a similar experiment to determine the proportion of alkali in the Geyzer water; but here I found it necessary to change a little the mode of ascertaining the point of saturation,

The water of Geyzer, by means of the sulphureous gas, which it contained in greater quantity than the other, and perhaps also by means of some of the other ingredients which it contained, and which gave it a light yellowish colour, produced such a change in the colour of litmus, that it could not be employed, as in the last experiment, by mixing it with the acidulated water, and boiling them together; the purple of the

litmus was changed to an orange, which could not be made to return to blue or purple, although I added a quantity of alkali; which rendered the liquor very evidently alkaline, when it was examined by other trials. I therefore had recourse to the common method, which I had formerly practised in many other experiments of a similar nature, I mean the use of linen rags, or bits of cambric, which had been tinged with an infusion of litmus. A little bit of these, when touched with a liquor that is in the smallest degree acid or alkaline, has its colour changed from the purple to red or blue. This method is, next after the one employed in the last experiment, the most nice that I know; provided that, in having recourse to it, we remember what was remarked in the former experiment, that the litmus colour is affected by acids in general much more easily than by alkalis; and that, though a liquor contain a small quantity of alkali, if this be saturated and super-saturated with fixed air, the first effect of such liquor upon the stained paper, will be to change it towards a red. This tint of colour, however, being produced by the superfluous aerial acid, is made to disappear, by drying the bit of cambric. The colour of it, while drying, will quickly change from the red to purple, and from that to blue, in consequence of the evapo-

cation of the superfaturating air. Being apprised of this particular, I first made some preparatory experiments, with gr. 1000, and also with gr. 10,000 of the Geyzer water, and afterwards a more satisfactory one with gr. 10,000 of the same, in the following manner:

To gr. 10,000 of the Geyzer water, I added gr. 400, accurately weighed, of the largely-diluted vitriolic acid, and began soon after to evaporate the water, by boiling it gently in a thin-bottomed glass. The above quantity of acid I knew to be considerably more than what was sufficient for saturating the alkali.

The water was boiled until it was reduced to a quantity little exceeding gr. 3000. I then added gr. 84.5 of the dilute solution of salt of tartar, and boiled the water again gently until it was reduced to gr. 2000. In weighing such small quantities of acid, or alkaline liquors, as were added to the water in these experiments, it is easy to adjust the weight with the greatest precision, by dipping the end of a slender glass rod, or of a pointed slip of paper, into the fluid. By these means, we can take up a quantity of it, as small as we please; and this method I likewise used, when I meant to add

these fluids gradually, and by very small quantities at a time, to any mixture. The end of a slender glass rod was dipped into them, and afterwards transferred into the mixture.

When I now examined the above boiled water, by means of the tinctured paper, or linen rag, I found it reduced to the exact degree of saturation which I desired; that is to say, it scarcely produced a change in the litmus colour, or if any change was produced, it was only a vergency towards the red, which was scarcely perceptible; and when the state of saturation was varied from this point, by an addition of 3 grains of the largely-diluted vitriolic acid, or by an equivalent quantity of the alkaline solution, the tint of the colour was remarkably changed towards the red or towards the blue. Supposing therefore the above state of saturation exact, and I believe it to be the most exact that could be depended on, the quantity of largely-diluted vitriolic acid, employed in saturating the fossil alkali of the water, was gr. 163.4; for the whole quantity added was gr. 400, and the salt of tartar of the gr. 84.5, of the dilute solution had required gr. 236.6 for its saturation. It follows, therefore, from the essays I had made, of the power of this diluted acid, in satu-

rating the pure or caustic fossil alkali, that the unsaturated quantity of this alkali, contained in the gr. 10,000 of the water, was gr. 0.952, which is equal to gr. 1.587 of the same alkali combined with air and evaporated to dryness, or gr. 4.409 of the same in a crystallized state.

The reason for boiling these waters, with the quantities of acid which I had added to them, in these last experiments, is sufficiently obvious. The abundance of acid was meant to insure the complete saturation of the whole of the alkali, and separation of it from the siliceous earth; and the boiling promoted the same purpose, both by means of the heat which was applied, and also by bringing the acid and alkaline particles the nearer to one another, while the water evaporated.

A doubt may, however, possibly arise in the minds of some of my readers, whether this boiling of the water might not be attended with the dissipation of some part of the superfluous acid, which was not neutralized by the alkali of the water; and if any part of the acid was dissipated, the conclusions concerning the quantity of the alkali would be necessarily erroneous,

To remove this scruple, I took gr. 10,000 of distilled water, and added gr. 112 of the diluted acid. This mixture was then boiled down, in the same manner as the Iceland water; that is to say, in a glass which had an oval, or nearly globular body, about five inches deep, with a neck as long, and half an inch wide. This glass was placed in a shallow sand-heat, the bottom of which was a flat iron plate. The boiling was continued until three fourths of the water were evaporated, and then, removing it from the fire, I added gr. 40 of the dilute solution of salt of tartar. This neutralized it exactly, and shewed that no part of the acid had been dissipated in boiling; and it continued to shew the signs of sufficiently exact saturation, after I had evaporated it further to the weight of one ounce, in which state any superfluous alkali, by being less diluted, would have been more easily discernible.

*Experiments to determine the Nature and Quantity of
the earthy Matter.*

Having thus determined the quantity of unsaturated alkali in these Iceland waters, my attention was next turned to the earthy matter. A small part of this

earthy matter came into view in the boiled and neutralized portions of these waters with which I had made the above-described experiments. The neutralized liquors were a little muddy, and deposited slowly a small quantity of sediment, which collected itself closely to the bottom of the glass, and adhered to it slightly. This sediment in the *Rykum* water was deeply tinged with the colouring matter of the litmus; in the *Geyzer* water, it had a brown tinge, and there was a little more of it than in the other. I collected these sediments, by first decanting the greater part of the liquor from them, and afterwards filtrating the rest in a small filter, in which the sediment was washed, by passing distilled water through it several times. Being then dried on the filtrating paper, it contracted greatly, and was divided by fissures into a great number of small parts, as would have happened to fine clay, had the same quantity of it been dried on paper in a similar manner; and when it was separated from the paper, and further examined, it shewed the qualities of an argillaceous earth, combined with a small quantity of colouring matter. This appeared by the following experiments:

1. I put some of it, which I had procured in different experiments, into a platina spoon, and made it red hot. While heating, it first became black, then underwent a slight inflammation, and afterwards became white, without changing its external form, being only a little contracted in its size, and diminished in its weight.

2. To another small mass of it, laid on a plate of glass, I added a drop of aquafortis, which neither effervesced with it, nor dissolved it, but only changed the colour to a paler red.

3. Another small portion, which had been gently calcined, was well mixed with an equal weight of the aerated fossil alkali, and then exposed to a strong heat in the platina spoon. The alkali was quickly melted, and became caustic; but I could not by its means bring the earth into fusion, or if any was dissolved by the melted alkali, it was only a very small portion, not perceptible by the appearances.

4. Nor did I succeed much better, when I tried to melt or dissolve it, by means of borax, heated on charcoal, with the blow-pipe. A little mass of this earth continued undissolved in the melted borax, and without

any appearance of effervescing with it, until I was tired of the experiment.

This earth therefore cannot be any other than the argillaceous. Had it been the filiceous, it would have been melted with the alkali into a transparent glass, which happened easily with different specimens of pure filiceous earth, subjected to the same trial; and had it been any of the alkaline earths, the borax would have dissolved it quickly with effervescence. The quantity of this earthy sediment, from either of these neutralized waters, was very small. From gr. 10,000 of *Rykum* water, I could only collect a quantity, which, after receiving an obscure red heat, weighed the twentieth part of a grain; from the same quantity of the *Geyzer* water, I got about 38 or 39 hundredths of a grain.

In one of my experiments with *Rykum* water, I got this argillaceous earth from it by another process. I had a dry extract, obtaining by evaporating gr. 20,000 of this water, and which weighed gr. 16 $\frac{1}{2}$. Thirty grains of aquafortis were added to it. This aquafortis was made up of equal parts of the strongest nitrous acid and water. The extract was digested with it six or eight hours, and then distilled water being added, the

mixture was filtrated in a small filtre, to separate the clear acid liquor from the undissolved matter. The filtrated acid liquor was then saturated, and a little more than saturated with a pure aerated alkaline salt, and the saturated mixture was heated to a boiling heat. It became muddy, and deposited a small quantity of sediment like mucilage, which being collected by filtration, and dried, and heated to an obscure red heat, weighed just one tenth part of a grain, and had the qualities above enumerated, which shewed that it was an argillaceous earth. In another experiment, I digested an extract of *Geyzer* water with strong vitriolic acid, and thus got from it a similar earth; but the quantity of it was very little greater than that which I had got by subsidence from the neutralized and boiled part of the same water, in the experiments above described.

The greater part, however, of the earthy matter had not yet made its appearance; I mean the siliceous earth. It still remained in a state of perfect dissolution in the neutralized and boiled mixtures above described, some part of which had actually passed through filtrating paper; and I learned by other trials, that the whole of these neutralized mixtures might have been filtrated, without danger of separating any part of the

siliceous earth from the water, by that operation. This is a consequence of the singular nature of the siliceous earth, several properties of which, hitherto unnoticed, or not exactly described, I became acquainted with in the course of these experiments.

We have no experience of the possibility of dissolving this earth in its concrete state by water alone; but if it be dissolved in water, by means of an alkaline salt, although we afterwards completely saturate the alkali with an acid, the earth thus separated, provided there is enough of water, will not subside; it will remain dissolved; the mixture will appear perfectly transparent, and will pass through the filtre without the smallest difficulty. To gr. 1000 of the *Geyser* water, I added more than enough of acid to saturate the alkali. I then boiled the mixture a little while, until a small part of it only was evaporated, and I set it aside in a quiet place. I know it contains a little more than half a grain of siliceous earth; but after standing twelve months, there is not the smallest appearance of separation, the mixture is still perfectly transparent and fluid in every part of it, though it be decidedly acid; and I know, that had it been boiled down to a proper degree, a separation of the siliceous earth would have happened

in a short time. I learned this by another experiment with *Rykum* water. To gr. 1000 of this water, I added a quantity of acid more than sufficient for saturating the alkali. The water was then boiled till it weighed only 138 grains, and it was set up in my closet to remain undisturbed. In about eight days, the transparency of it was a little diminished, and afterwards there was a very slow subsidence of the matter which had produced this effect. It formed gradually, at the bottom, a stratum of some thickness, which was a little less transparent than the clear water above, and was thereby distinguishable from it. After a week or two more, I poured off the clear water entirely, without disturbing the sediment, which was in fact a tender jelly, adhering to the bottom of the glass, and the upper surface of which was level and smooth. I knew the quantity of siliceous earth contained in it; and comparing this with the weight of the water when reduced by boiling to gr. 138, I found the proportion of the earth to that quantity of water to be as 2.68 to 1000; and having weighed the jelly by itself, the proportion of siliceous earth to the water in it, supposing that it contained the whole of the earth, was 10.88 to 1000. In another experiment, in which a similar mixture had been less boiled, and in which the siliceous earth bore to the

water the proportion of 2.1 or 2.2 to 1000, I found a soft jelly formed at the end of 40 days. And in another, in which the boiling and evaporation was continued until the jelly began to be formed in the upper part of the liquor while it was boiling, I found the proportion of the siliceous earth to the remaining water to be nearly as 3 75 to 1000.

After this jelly is once formed, I never could bring it again into a state of dissolution by water alone, whatever quantity of this last was added.

It appears therefore by these experiments, that when siliceous earth, united with an alkali, is dissolved in 1000 times, or in more than 500 times its weight of water, it will not separate or subside from that quantity of water, although we separate or disengage the alkali from it. The particles of it, placed at that distance, do not act on one another by their attraction of cohesion or concretion. It is necessary, in order to enable them to attract one another, that they be brought nearer, by diminishing the quantity of the water, until it be less than 500 times the weight of the earth. When this is done, they will enter into a state of cohesion, sooner or later, according as the water has been more

or less diminished. But this state of cohesion into which they first enter is also remarkable. The force of it is exceedingly weak, and it takes place while the particles of the earth are still at a considerable distance from one another. They therefore retain and entangle among them a large quantity of water, amounting to about 100 times their own weight, and perhaps more than 200 times their bulk, with which they form a consistent jelly, almost perfectly transparent.

It may be asked here, what prevents the particles of this earth from approaching one another more nearly, and entering into a state of stronger cohesion? We may, if we please, imagine that they retain round each of them, by chemical attraction, a quantity of water, which forms a little sphere, or polyhædron, with the particle of earth in its centre. Thus, each particle is prevented from coming within a smaller distance of the other particles around it, than the diameter of that sphere; but let the water of these spherules be diminished in quantity by evaporation, in consequence of heat, or the attraction of the air, the particles of the earth will immediately enter into a state of closer connection and stronger cohesion, of which we have examples in the excessive contraction of the jelly, while

It is dried up into crusts, and in those circles of thin incrustation which were formed on the sides of the glass vessels, while the waters were evaporated to dryness in the first experiment, the particles of which were so strongly united to one another, and to the surface of the glass, that they cost me much trouble and time to scrape them off with a knife.

When such a concretion is once formed of this earth, and afterwards receives frequent additions of the same matter, which insinuating itself into the pores of the concretion, is fixed there, and increases its density and solidity, the mass may in time acquire a surprising degree of hardness. The petrifications of *Geyzer* are undoubtedly formed in this manner, and some of them are so dense and hard, that they are scarcely distinguishable from agate or calcedony.

After making these observations on the nature of the siliceous earth, the proper method for extracting it from the above boiled and neutralized portions of these waters, was sufficiently obvious. I separately evaporated them to dryness with a gentle heat in two china cups, carefully washing every drop of them from the glasses into the cups with distilled water, and then

taking the dry extracts out of the cups, I put them separately into small filtrating papers, and passed distilled water through them repeatedly, until all the saline matter was washed away. The papers being then carefully dried, I found the earth in them exceedingly spungy, fine, and tender. The quantity of it obtained in this state from the gr. 10,000 of *Rykum* water, was gr. 3.8, which were reduced by the action of an obscure red heat to gr. 3.73 nearly. From the same quantity of the *Geyzer* water, I got gr. 6.8 of the dried earth, which, by a similar heat, were reduced to gr. 5.4, and these gr. 5.4, being digested with aqua-fortis, and again washed with distilled water, to extract any argillaceous earth that might remain in them, I obtained only gr. 0.1 of this earth, which, added to the quantity obtained before, makes up gr. 0.48 of the argillaceous earth, from the gr. 10,000 of *Geyzer* water, the remaining gr. 5.3 being pure siliceous earth. Some of it was melted into a perfect glass in the platina spoon, with one half of its weight of aerated fossil alkali evaporated to dryness. The diminution of the weight of the dried earth, from gr. 6.8 to gr. 5.4, which happened when it was gently calcined, proceeded from some inflammable matter, which adhered to it at first, and gave it a yellowish colour. This

colour changed first to black, and afterwards to a pure white, during the calcination. The inflammable colouring matter might have been received in part from the vessels in which the water was brought, some of which were tainted with the odour of spirituous liquors, or the water might have got a part of it from subterranean strata of clay, or other earths containing inflammable matter.

Experiments to learn the Quantity of the Neutral Salts.

The only ingredients of these waters, the quantity of which had not yet been examined, were the neutral salts. The preliminary experiments, and the appearances observed in the watery solutions of the extracts of these waters, gave me reason to be satisfied, that these neutral salts were partly common salt and partly Glauber's salt. To ascertain the quantities of them, I made the following experiments: I had some common salt, which had been refined by a second crystallization, and was in solid dry and large crystals. Of this I weighed ten grains exactly, which were dissolved in about half a pound of distilled water. I then added a solution of silver, which contained a little super-

fluous acid. The silver was precipitated in the form of luna cornea, or argentum muriatum; and I took care to add rather more than the quantity which the ten grains of common salt could precipitate. The luna cornea, after complete subsidence, and decantation of the saline water from it, was carefully collected on a small filtre, and well washed with distilled water, and thoroughly dried and weighed. I thus learned, that 100 parts of common salt are sufficient to give 235 of luna cornea. This enabled me to learn, by similar experiments, how much common salt is contained in the Iceland waters, and I found that the quantity contained in 10,000 grains of *Rykum* water was gr. 2.90, and in the same quantity of the *Geyzer* water, I found there was gr. 2.46 of common salt. Some of my readers may, perhaps, be inclined to suspect, that the Glauber's salt contained in the Iceland waters might, by means of its vitriolic acid, contribute to the precipitation of a part of the silver; but experiments have satisfied me, that a small quantity of vitriolic acid, or of any vitriolic salt, dissolved in a large quantity of water, does not precipitate silver;* and to prevent any part of the silver being precipitated by the

* See the Appendix to this paper.

alkali of the water, I added of purified aquafortis, more than enough to saturate the alkali, before I added the solution of silver.

Another set of experiments, on the same plan, but made with Glauber's salt and the solution of barytes, in place of common salt and solution of silver, enabled me to ascertain with equal exactness the quantity of Glauber's salt contained in these waters. I first learned, that if pure Glauber's salt be perfectly exsiccated, by evaporating the water that is in its crystals, ten parts of this exsiccated salt are sufficient to precipitate as much barytes, from its solution in muriatic acid, as will form 17 of barytes vitriolica. This fact being ascertained, I added some of the dissolved barytes to separate portions of the Iceland waters, so long as any muddiness and precipitation was produced; and I carefully collected, washed, dried, and weighed the precipitates.* I thus learned, that the water of Rykum contains in gr. 10,000 of it, as much Glauber's salt as

* The method by which these small quantities of sediments and precipitates were collected and weighed, is explained in the Appendix to this paper.

would give gr. 1.28 of exsiccated Glauber's salt, and the water of Geyzer as much as would give gr. 1.46.

In making these last experiments also, I added some purified nitric acid to the Iceland waters, to prevent any precipitation of the barytes which might have been occasioned by the alkali of the water.

In reviewing the experiments I have now described, if we neglect the small quantity of sulphureous gas, the contents of these waters will appear as follows:

In gr. 10,000 of *Rykum* water there are,

Of caustic fossil alkali	-	-	-	gr. 0.51
Argillaceous earth	-	-	-	0.05
Siliceous earth	-	-	-	3.73
Common salt	-	-	-	2.90
Glauber's salt when exsiccated			-	1.28
<hr/>				
Total	-		8.47	

In gr. 10,000 of *Geyzer* water,

Caustic foffil alkali	-	-	-	gr. 0.95
Argillaceous earth	-	-	-	0.48
Siliceous earth	-	-	-	5.40
Common salt	-	-	-	2.46
Glauber's salt exsiccated	-	-	-	1.46
				—
Total	-			10.75
				—

These quantities of the ingredients, as determined by the above experiments, exceed the quantities of dry extract which I obtained by evaporation. Gr. 10,000 of the *Rykum* water gave, by evaporation, gr. 8.25 of dry extract, and the same quantity of *Geyzer* gave gr. 10 only. This difference, however, can easily be accounted for. It is well known, that common salt, and other salts, suffer some loss by evaporation, when watery solutions of them are evaporated to dryness; and the odour which was perceived in the end of the evaporation of these waters, made me suspect that a little of the salt might have been lost. There was

therefore no reason to expect, that the result of the analytical experiments would tally exactly with the extract by evaporation. I was rather surprised and pleased to find that they came so near, and I am perfectly satisfied that this analysis is as complete and exact as it was in my power to make it, with that quantity of water which I got for this purpose.

The proportions of the above enumerated ingredients to the water in which they are contained, shew the quantities of them contained in an English gallon of 231 cubical inches, or 58,484 grains, which are as follows:

In an English gallon of *Rykum* water.

Caustic fossil alkali	-	-	-	gr. 3.
Argillaceous earth	-	-	-	0.29
Siliceous earth	-	-	-	21.83
Common salt	-	-	-	16.96
Glauber's salt exsiccated	-	-	-	7.53

In an English gallon of *Geyzer* water,

Caustic fossil alkali	-	-	-	gr. 5.56
Argillaceous earth	-	-	-	2.80
Siliceous earth	-	-	-	31.38
Common salt	-	-	-	14.42
Glauber's salt exsiccated	-	-	-	8.57

Having now stated the several ingredients of these hot springs, and their proportions, the principal questions which remain to be considered, are, how is the siliceous earth dissolved in them, or combined with the water? Has hot water alone a power to dissolve this earth, or was it dissolved by the medium of the alkali only? And how came the salts which we find in these waters, and the sulphureous gas to be combined with them? As all attempts to answer these questions must be conjectural, different opinions will be formed concerning them; and I may offer what I have imagined, without its being thought necessary to make an apology. Professor BERGMAN considered the siliceous earth in these waters as dissolved by the power of the hot water alone; and supposed, that water, aided by excessive heat, became a solvent of this

species of earth. He formed this opinion, however, under disadvantageous circumstances, and from a partial view of the subject. He only knew that this earth is actually dissolved in these waters, and deposited by them; and that they spring out of the ground of a full boiling heat, with appearances of their having been hotter below. He did not know what other ingredients they contained along with the earth. As we now know they contain an alkali, which is a powerful medium for combining this earth with water, I do not think that the power of water alone to dissolve it can be admitted, until it is proved by direct experiments; and I am not of opinion that these will succeed. I am persuaded, that both the siliceous and the argillaceous earths have been dissolved by the medium of the alkali, but, at the same time, that the violent and long-continued heat contributed greatly, and was even necessary to this dissolution. The proportion of the caustic alkali to the earthy matter in one of these waters, is as $13\frac{1}{2}$ to 100; in the other it is 16 to 100. When we form artificial compounds of siliceous earth and alkali in these proportions, we find that cold water has no power to dissolve them, though boiling water, by length of time would certainly act on them. Even cold water, or the humidity of the earth, is well known

to penetrate the hardest glass that is exposed to it for years or for ages; and I have had the experience of the power of hot water to act on glass, when I have distilled water in the same glass retorts a great number of times, or evaporated water often in other glass vessels. Their internal surface was evidently affected by the continued action of the hot water. Its first effect is to soften thin laminæ at the surface of the glass, and to make them separate from that surface, in consequence probably of their being swelled and extended by the water penetrating into them; and by a longer action of the water, there is no doubt that they, or some part of them, are completely dissolved.

Those who may have objections against admitting, that a boiling heat, and great length of time, are sufficient aids to enable water to dissolve a compound of the siliceous earth with such a small proportion of alkali, may imagine this earth to have been at first combined with a larger proportion of alkali, than that we now find combined with it, and that after it was dissolved in the water, a part of this alkali was neutralized by acid vapours, or acid substances, which the water found in its way towards the surface.

On the whole, however, the supposition which appears to me the most probable is, that common salt and Glauber's salt, conveyed by sea-water, or contained in fossils formed from sea-plants, have been applied, under the influence of a violent heat, to some of the numerous earthy and stony strata which contain mixtures of siliceous and argillaceous earth; that those salts have been in part decompounded, by the attraction of these earths for the alkali of the neutral salt, part of the acid has been dissipated, or changed into sulphur, and sulphureous gas, by the action on it at the same time of inflammable matter, which we know to be present in many of the strata; and that the compound of alkali and earthy matter has afterwards been long exposed, and continues exposed, to the action of the hot water. By such a supposition, we can imagine how the several ingredients of these hot springs became dissolved in them; and this supposition appears the more probable, when we attend to the accurate observations of Mr. STANLEY, on the nature of the country, and state of the soil, in which these two hot springs are found. The rocks and mountains, which are at a small distance, or in the immediate vicinity of each of them, are formed chiefly of different kinds of lava. The lower country and soil at the foot of these,

and in which the springs rise, is composed of fragments of these lavas; but in digging into this soil or rubbish, to a small depth only, these fragments are every where found resolving, or resolved, into a matter, like clay. At a certain depth, the fragments of some species of lava remain entire and hard, while the rest are changed. At a greater depth, even these more durable kinds are found to have undergone the same change with the rest. As this change is produced by the constant action of the hot water, it probably depends on a gradual dissolution and extraction from these lavas of some of their ingredients, which are dissolvable in water; and those which we have actually found in the water may have been some of these. But I offer all this as a conjecture only, which every person who does not like it, is at liberty to reject.

I shall venture further to offer another conjecture, which some particulars I learned by MR. STANLEY's voyage to Iceland have suggested to my mind. It is concerning the origin of the pure sulphur, which is found at the surface of the earth, in the neighbourhood of many volcanos in different parts of the world. In Iceland, there are places in which sulphur is thus found in very great quantity, covering the surface of

the ground, and that of the stones and rocks, in form of a thick crust, and constituting what are called sulphur banks. This was seen in Iceland in particular spots, in which there were very strong sulphureous hot springs, which emitted such a quantity of sulphureous or hepatic gas, that the air all around was infected with it to the highest degree, and the water itself was muddy and black, and constantly boiling. Now, as we know that vital air has the power to decompose this gas, and to make it deposit the sulphur which it contains, I am of opinion, that the sulphur which appeared in such quantity in the vicinity of these springs, had been deposited and accumulated in this manner from the hepatic gas, which these strongly-sulphureous springs have emitted during a great length of time.

APPENDIX.



IN order to shew, that such a small proportion of a vitriolic salt as is contained in the Iceland waters, has not the power to precipitate silver, I dissolved gr. 0.3 of exsiccated Glauber's salt, in gr. 2000 of distilled water, which thus contained a proportion of Glauber's salt rather greater than that contained in the Iceland waters. I then added five drops of purified aquafortis, and five drops of the solution of silver. The mixture remained transparent several days. I afterwards added gr. 0.7 more of the exsiccated Glauber's salt, without diminishing in the least the transparency of the mixture. After a few days more, I added gr. 9 of the exsiccated Glauber's salt. This produced a diminution of transparency, and the sediment subsided in a few

days more. This sediment being carefully collected and dried, weighed gr. 0.3; but the clear liquor which had been filtrated from it, still retained the greater part of the silver. I therefore added to it some pure common salt, which precipitated all the rest of the silver, and this last precipitate, being also collected and dried, weighed just one grain.

When I examined these two precipitates by means of the blowpipe, their qualities appeared to me so much the same, that I suspect the first was produced by a small quantity of common salt, contained imperceptibly in the Glauber's salt. If there were 12 or 13 parts of common salt in 1000 of the Glauber's salt, they were enough to produce the above quantity of the first precipitate; and as Glauber's salt is prepared from common salt, we can easily understand how a small quantity of the common salt may remain in it.

For the sake of those who may have occasion to undertake such chemical inquiries as that described in the above paper, I shall here mention the method by which I collected and weighed the small quantities of sediments or precipitates, which I obtained in some of these experiments. In most cases, the turbid liquor

was left at rest in a cylindrical glass, until the sediment was so well collected at the bottom, that the greatest part of the liquor was quite clear, and then this clear part was carefully decanted; the rest, which could not be decanted without disturbing the sediment, was shaken, and poured gradually into a small filter, that the sediment might be collected upon the filter, and afterwards washed on it, by passing distilled water through it repeatedly. And this part of the process was much facilitated by the preparation of the filter, and some other little manœuvres. When, for example, I used for my filter a piece of paper about four inches in diameter, I began by folding it, and giving it the proper form; then I spread it open again, and warming it, I applied melted tallow or bees wax to the margin of it all round, until it was soaked therewith to the breadth of a full inch from the margin inwards, the middle part of it being carefully preserved clean. As soon as this was done, and while it was yet a little warm, it was folded again into the proper form of a filter, and retained in that state until it was cold. On a filter prepared in this manner, it is much more easy to collect a sediment together, and to wash it clean, than on an ordinary filter. In the first place, no part of the sediment adheres to or is deposited on

that part of the paper which was soaked with tallow. The whole is collected on the clean part of the paper, and after it is collected there, I condense it into the centre as much as possible, by dropping the distilled water on the margin of that clean part all round, or a little above that margin, by which practice the scattered particles of the sediment are washed down into the bottom. Sometimes I apply what may be called a capillary jet of the distilled water, directed with force to those parts of the scattered sediment which are more difficultly moved. Having thus condensed the sediment as much as possible, the filtre is left in a cool place to dry. When it is perfectly, or nearly dry, I spread it flat on a table, and cut away all that part which was soaked with tallow, and also those parts of the clean paper to which the sediment does not adhere. The rest, with the sediment on it, is then well dried before a fire, and weighed, and the weight of it marked down; and, lastly, in order to know how much of this weight is made up by the paper, I take care, before I prepare the filtre, to chuse another piece of the filtrating paper, equal in thicknes to the one of which the filtre is made. This equality of thicknes is judged of by holding the two pieces between the eye and the light; or, for greater security, bits of the two pieces

may be cut off, exactly similar, and equal in form and size, and their weight compared, and allowance may afterwards be made for their difference of weight, if there be a difference. After weighing the bit of paper with the sediment on it, a proper bit of the reserved paper is laid flat on a smooth table or plate of glass, and the paper on which the sediment had been collected is laid over it, with the clean side undermost; then a bit of card, somewhat less, but nearly of the same form, is pressed down on both the papers, and, with a pair of sharp-pointed scissars, or a pen-knife, the undermost paper is cut exactly to the same shape and size as the uppermost, and is afterwards weighed. The weight of it being deducted from that of the former, we thus learn the weight of the sediment, with a greater degree of exactness, and with less trouble, than by any other method which I have been able to contrive. To complete this article, I beg leave further to add, that the most ready and convenient way to soak the margin of the filtrating paper with tallow or wax, is to hold it above a lighted candle, at a proper distance for warming it a little, and then melting the end of another candle, apply it immediately to the warmed paper, and repeat this, until the paper is prepared as above directed. The prominent part of the

wick of the candle, which is thus melted, becomes a sort of pencil, which holds the melted tallow or wax, and facilitates the application of it, and the wick of a tallow candle, on account of its being thicker, is fitter for this purpose than the wick of a wax one.

The last remark on these experiments I shall now make is, that in the trials with the solution of barytes, the barytes vitriolica was formed in particles so very minute, that they did not all remain at first upon the filtre. Some of them passed through it, and made the filtrated liquor a little muddy; but by making this muddy liquor pass through the filtre a second time, it was made quite clear, the whole sediment being thus collected on the filtre.







